Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Recommendations Approved by World Radiocommunication Conference Advisory Committee	)))	**IB Docket No. 16-185**

COMMENTS OF ONEWEB ON DRAFT RECOMMENDATION FOR WRC AGENDA ITEM 1.6

WorldVu Development Limited (dba "OneWeb") submits these comments in response to the Public Notice issued by the International Bureau on October 3, 2018, in the above captioned proceeding (the "PN").[1] The PN seeks comments on the World Radio Communications Conference Advisory Committee's ("WAC") draft recommendations in Attachment A to the PN and NTIA's draft proposals in Attachment B to the PN. These issues will be considered at the 2019 World Radiocommunication Conference ("WRC-19").

Introduction

Agenda Item 1.6 is "to consider the development of a regulatory framework for non-GSO FSS satellite systems that may operate in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space to Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space), in accordance with **Resolution 159** (WRC-15)." The WAC Industry Working Group covering this agenda item did reach a consensus ("Industry View").[2] However, NTIA proposes a counter

[1] *See International Bureau Seeks Comment on Recommendations Approved by World Radio Communication Conference Advisory Committee*, Public Notice, IB Docket No. 16-185, DA 18-1017 (October 3, 2018) ("PN").

[2] *See id.*, Attachment A at p.p. 181-192 (presenting the Industry View in Document WAC/069).

view ("NTIA View").[3] OneWeb's comments generally support the Industry View and highlight certain difficulties with the NTIA View.

Background

All parties considered two main issues under Agenda Item 1.6:

1) ensuring that aggregate interference from all non-geostationary ("NGSO") fixed-satellite service ("FSS") systems does not exceed the aggregate protection requirements of geostationary ("GSO") FSS and broadcasting satellite service ("BSS") systems, and
2) ensuring that Earth exploration satellite service ("EESS") (passive) systems in the 50.2-50.4 GHz frequency range continue to receive protection from FSS systems in adjacent frequency bands after the introduction of NGSO FSS systems into those adjacent bands and possible consequential modifications to **Resolution 750** (Rev. WRC-15).

Discussion

A. Ensuring that aggregate interference from all NGSO FSS systems does not exceed the aggregate protection requirements of GSO FSS and BSS systems.

In general, OneWeb supports the Industry View on this issue but notes that some aspects warrant further development. For example, the text of the proposed Draft New Resolution does not sufficiently explain the mechanisms nor the consultation process for determining how interference from multiple NGSO FSS networks will be aggregated and checked against interference criteria. *Resolves* 4 of the **Draft New Resolution [A16]** proposes a "specialized software tool" for the calculation of aggregation of interference from all NGSO systems. However, *resolves* 4 is unclear whether the specialized tool would be approved by and/or developed in consultation with the ITU-R, or whether operators can use common, off-the-shelf software that they may even develop themselves. OneWeb believes that it would be better if the Radiocommunication Bureau were not involved in either running this software tool or making determinations on the results. The GSO and NGSO FSS operators can fully do the calculations, undertake the technical discussions, and negotiate any trade-offs without any involvement from the Radiocommunication Bureau. Nevertheless, the Bureau's assistance can always be sought out as per Article 13 in the Radio Regulations, even without mention of the Radiocommunication Bureau in a Resolution.

The Industry View proposes, in Annex 1 to **Draft New Resolution [A16]**, a list of NGSO FSS system parameters to be supplied under I-2 "Non-GSO satellite system constellation parameters" to derive aggregate interference. However, this list is limited and may not enable a full

[3] *See id.*, Attachment B at p.p. 35-48 (presenting the NTIA View in Document WAC/074).

characterization of the aggregate interference. OneWeb supports moving forward with the Industry View, noting that the details of the methodology in **Draft New Resolution [A16]** are a work in progress and will need to be refined after the December CITEL meeting.

The NTIA View, in the corresponding **Draft New Resolution [USA – A16]**, relies upon aggregate equivalent power flux densities ("epfd") produced by NGSO satellite networks to establish whether GSO networks are protected. While epfd may be one possible quantification of interference, OneWeb notes that Working Party 4A has identified significant inefficiencies when implementing epfd limits to determine whether a GSO network is protected. For example, Annex 4 to document 4A/826 from the July 2018 Working Party 4A meeting states:

> . . . the methodology to determine the epfd limits based on interference profiles is extremely dependent on the characteristics of the systems being evaluated. While epfd masks can be developed for individual systems, it is not spectrally efficient to define a single epfd mask that would allow all non-GSO system design types (LEO, HEO, MEO) to operate while assuring GSO protection. (§ 4.3)

Furthermore, the methodologies in the NTIA View seem to be taken from earlier texts that the United States submitted to Working Party 4A, which have subsequently been replaced by the example resolution provided in the Industry View. Hence, the NTIA View may be incomplete as compared to the Industry View that represents more evolved methodologies. Thus, given the lack of completeness and recognizing that any sharing methodology developed under Agenda Item 1.6 should be completely devoid of epfd limit tables, OneWeb opposes the current NTIA View.

B. Ensuring the continued protection of EESS (passive) systems in the 50.2-50.4 GHz band after FSS systems enter the adjacent bands and after possible consequential modifications to Resolution 750 (Rev. WRC-19)

The Industry View—on the protection of EESS (passive services) in the 50.2-50.4 GHz band—contains a proposed modification to **Resolution 750** (Rev. WRC-19) that applies to future NGSO FSS systems in the two adjacent 49.7-50.2 GHz and 50.4-50.9 GHz bands:

> For non-NGSO stations brought into use after the date of entry into force of the Final Acts of WRC 19 [1 January 2021]:
>
> - -13 dBW into the 200 MHz of the EESS (passive) band for earth stations having an antenna gain greater than or equal to 57 dBi
> - -23 dBW into the 200 MHz of the EESS (passive) band for earth stations having an antenna gain less than 57 dBi"

OneWeb is not opposed to these power density limits but notes that they are more restrictive than those imposed on GSO FSS systems.

The NTIA View for protecting EESS (passive) services in the 50.2-50.4 GHz bands proposes modifications of **Resolution 750** (Rev. WRC-19) that apply to future NGSO FSS systems for the two adjacent bands 49.7-50.2 GHz and 50.4-50.9 GHz:

> For stations brought into use after the date of entry into force of the Final Acts of WRC 19:
>
> - -58 dBW into the 200 MHz of the EESS (passive) band

Unlike the Industry View, the NTIA View is entirely one-dimensional because it only considers the needs of the EESS (passive) services and ignores the constraints on the FSS. There is very little balance between the FSS and passive sensing satellites with a proposal that only tightens FSS out-of-band emission ("OOBE") limits (on GSO and NGSO alike) to ensure compatibility. Moreover, there was no assessment as to the impact of more constraining limits on the FSS, and operational mitigation measures were not explored. Thus, the NTIA View is unacceptable.

Noticeably absent in the NTIA View is any mention of footnote **5.340.1**, which states:

> The allocation to the Earth exploration-satellite service (passive) and the space research service (passive) in the band 50.2-50.4 GHz should not impose undue constraints on the use of the adjacent bands by the primary allocated services in those bands. (WRC-97)

This footnote suggests a "condition of use" on the EESS (passive) services' utilization of the band. Consequently, the NTIA View proposes a revision of **Resolution 750** that is a violation of the requirement on EESS (passive) services' obligation to consider proposed modifications of **Resolution 750** that impact the use of the bands adjacent to the 50.2-50.4 GHz band.

When determining what OOBE constraints on earth stations in the 500 MHz wide adjacent bands (i.e., 49.7-50.2 GHz and 50.4-50.9 GHz), physical processes involved in the amplification of signals transmitted from earth stations must be considered. A real, practical amplifier will generate non-zero emissions in the adjacent 50.2-50.4 GHz band resulting from thermal noise emissions and intermodulation distortion. Under typical operation conditions, intermodulation distortion would result in a "spillover" power spectral density ("PSD") into the 50.2-50.4 GHz notch of approximately 18 dB below the level of the PSD modulated signal on either side of the notch yielding approximately -15 dBW in the 200 MHz passive band for a modulated signal having a PSD of 10 W/GHz. Clearly, significant reductions in the level of power falling into the 200 MHz passive band would be required to achieve the very low levels proposed in the NTIA View. The obvious choice for reducing the interference into the passive band would be a band stop filter. Providing sufficient rejection of the amplifier output by approximately 55 dB of rejection in the 50.2-50.4 GHz band would require an ideal 8-pole waveguide cavity band stop filter, which would in turn create significant transition bands on either side of the 200 MHz wide stop band due to a number of very real phenomena including:

- insertion loss (which reduces filter Q), even with silver plating to minimize the effect;
- matching variations; and

- thermal expansion and contraction, causing linear size variations in which filter parameters shift with temperature.

Considering all the above-mentioned mechanisms at work in addition to the expected performance of an ideal 8-pole filter, under the NTIA View, a 400 MHz transition band on either side of the stop band would be required for each earth station transmitting at a typical output level to be able to comply with the low limits proposed in the passive band. The attached study supports the detrimental impact analysis of utilizing a band stop filter as revealed by the above discussion. It can be clearly seen that the requested OOBE power density is far too constraining on the FSS.

Accordingly, the EESS (passive) protection criteria must not require the permanent implementation of a band stop filter on every earth station in the FSS because this would result in 800 MHz of spectrum loss for 100% of the time. Instead, OneWeb strongly supports the accommodation of operational mitigation methods that would significantly reduce spectrum unavailability commensurate with the 0.01% protection criteria required for EESS (passive) services.

Conclusion

OneWeb supports with the understanding of future modifications the Industry View on the issue of ensuring that aggregate interference from all NGSO FSS systems does not exceed the aggregate protection requirements of GSO FSS and BSS systems. OneWeb can also support the Industry View on the issue of protecting EESS (passive) services in the 50.2-50.4 GHz band.

Respectfully submitted,

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IMPLICATIONS OF EARTH OBSERVATION BAND (50.2 – 50.4 GHz) AND PRACTICAL FILTER PERFORMANCE ON USABLE BANDWIDTH IN THE 47-51GHz FSS BAND

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SOURCES OF SPURIOUS EMISSIONS IN THE 50.2-50.4GHz BAND

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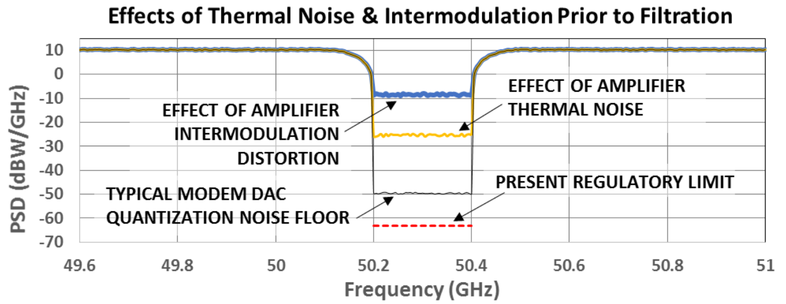
- Ideally, a system operating over the 47 – 51 GHz Fixed Satellite Services band would have zero emissions within the 50.2 – 50.4GHz Earth Observation band "notch"
- A real, practical amplifier will generate non-zero emissions in this notch resulting from several physical processes, including broadband thermal noise emissions and intermodulation distortion
- Broadband noise:
  - All amplifiers produce amplified noise at their output resulting from random electronic processes (Johnson noise in resistors, shot noise in diodes, etc.), which can be characterized by output noise power density (NPD)
  - A typical SATCOM amplifier would have an NPD of ~ -80 to -85dBm/Hz, so even with no input the amplifier would produce ~ -30dBW of noise in the 200MHz wide notch



- Intermodulation distortion:
  - Real amplifiers have non-linearities that produce mixing products
  - When a modulated signal is amplified with such non-linearities, mixing-product emissions, known as spectral regrowth, are generated adjacent to the edge of the intended signal spectrum
  - At typical operating conditions the "spillover" power spectral density (PSD) into a narrow notch (e.g., the 50.2 – 50.4 GHz notch) is ~ 18dB below the level of the PSD modulated signal on either side of the notch
  - For a modulated signal with a power spectral density of 10W/GHz, this would yield ~ -15dBW in the 200MHz notch
- The larger contribution to emissions in the notch will be intermodulation products

AN IDEAL 8-POLE BANDSTOP FILTER

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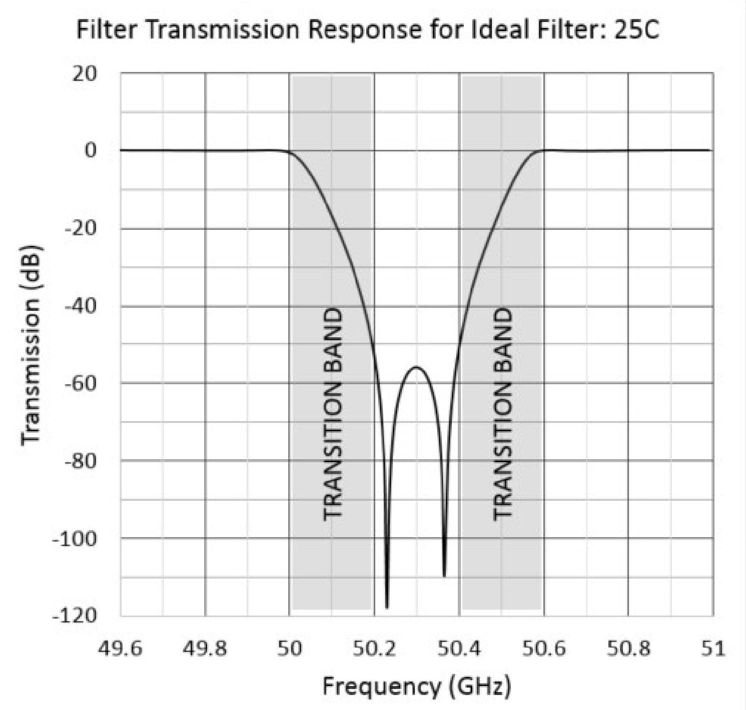
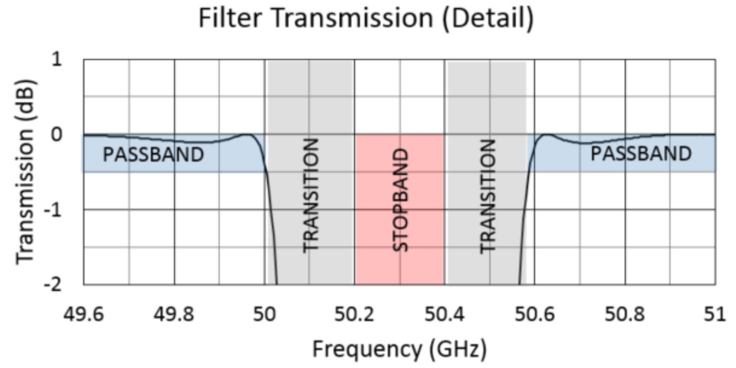
- Given the spurious emission (noise) contributions from
  - the modem source
  - thermal noise from the amplifier
  - intermodulation products from the amplifier,

  one approach is filtration of the amplifier output with a filter that provides ~55dB of rejection in the 50.2-50.4 GHz band
- An ideal 8-pole waveguide cavity bandstop filter could provide sufficient rejection, but the filter transitions from passband to stopband are ~200MHz wide on each side of the stopband
- ➢ with such a stringent emission requirement, even an ideal filter would sacrifice 400MHz of usable bandwidth in the 47-51 GHz band

- Real effects in the filter, such as thermal expansion/contraction, finite conductivity of the waveguide material, and machining variations cause further erosion of the usable bandwidth





PRACTICAL EFFECTS: FINITE CONDUCTIVITY (LOSS)

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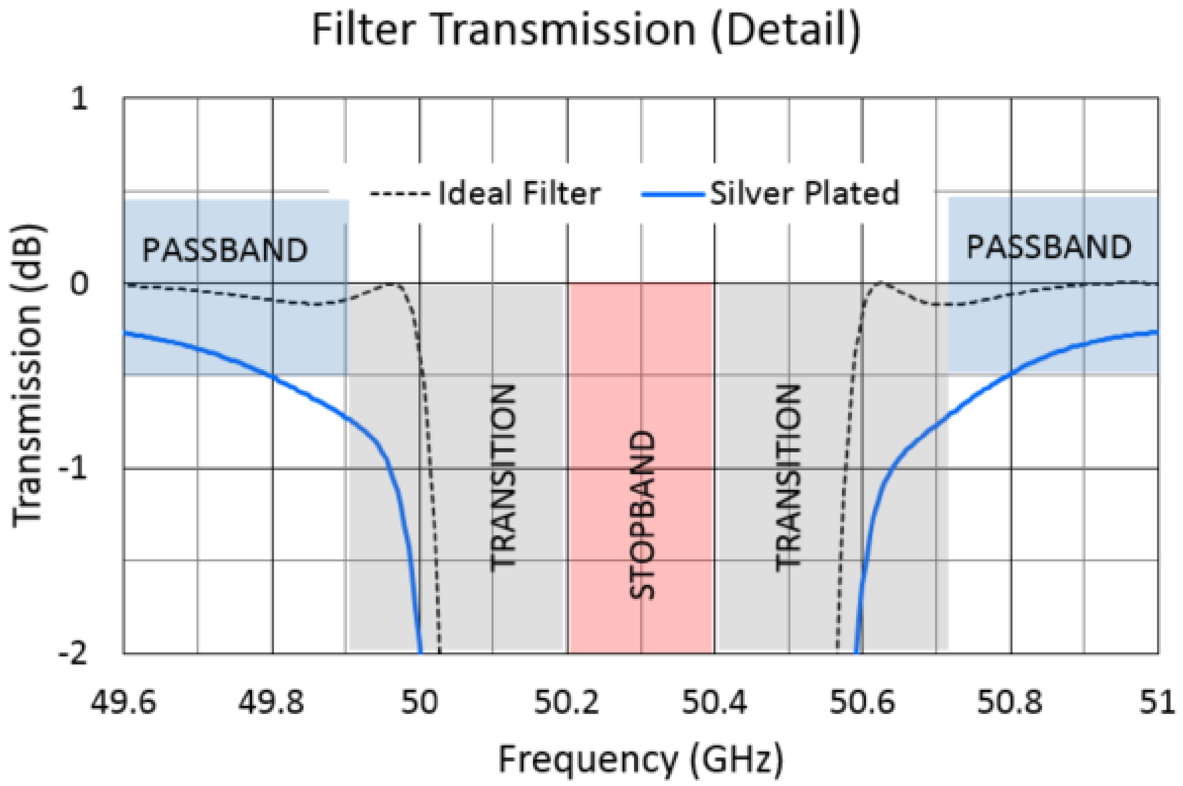
- Real filters are made of materials that are not infinitely conductive; this increases insertion loss and reduces filter Q, making the transition bands broader than for an ideal filter
- It is traditional to silver-plate surfaces of critical filters, which minimizes the impact of this effect, but does not eliminate it.
- The reduction in the filter Q moves the edge of the passband (the frequency at which the transmission is 0.5dB lower than the passband insertion loss) further from the notch by ~100MHz on each side

⇒ including filter loss, the transition bands consume 600MHz of the 47-51 GHz band



PRACTICAL EFFECTS: THERMAL EXPANSION/CONTRACTION

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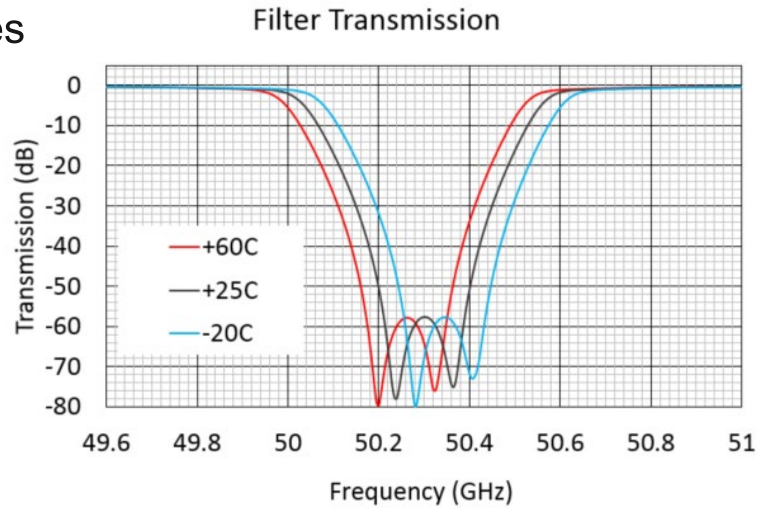
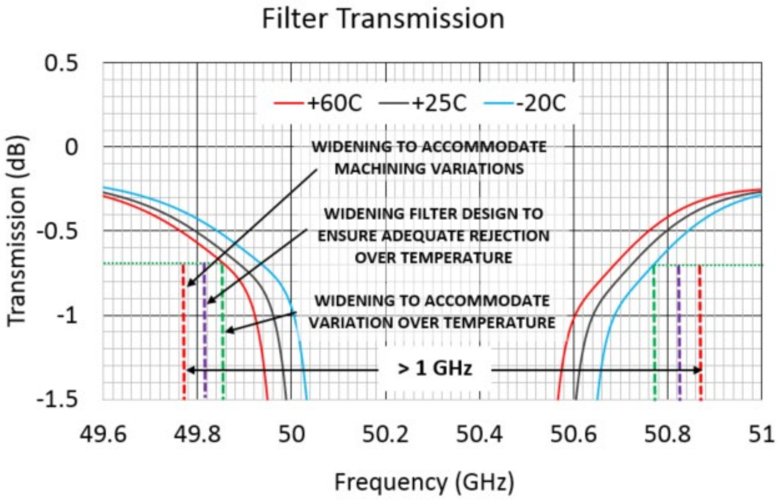
- Real filters are subject to thermal expansion and contraction with variation in temperature
- Exotic materials e.g., Invar can be used, but very small cavities and tight tolerances required for V-Band make mass-production using such materials impractical
- For aluminum, temperature variations up to 60C and down to -20C will cause linear size variations of ~0.1%, causing filter parameters to shift with temperature
- This expansion and contraction causes two effects
  - Shifts stopband, so that overall rejection across 50.2 – 50.4 GHz is diminished
  - Shifts transition bands, so more of the passband is eroded (on the low end at high temperature and at the high end at low temperature)
- For filter as shown (with loss), the integrated spurious emission power across the band is -75dBW/200MHz (5dB margin), but with thermal expansion effects:
  - -61dBW/200MHz at 60C
  - -59dBW/200MHz at -20C

⇒ Since filter rejection fails at -20C & 60C, filter would need to be ~80MHz wider

- Impact on transition bands consumes an additional 40MHz of usable bandwidth the low end of the band at 60C and at the high end of the band at -20C
- Machining tolerances will have a similar impact, likely requiring an additional allocation of 40MHz variation at each side of the notch





IMPACT OF RELAXING EMISSIONS LIMIT

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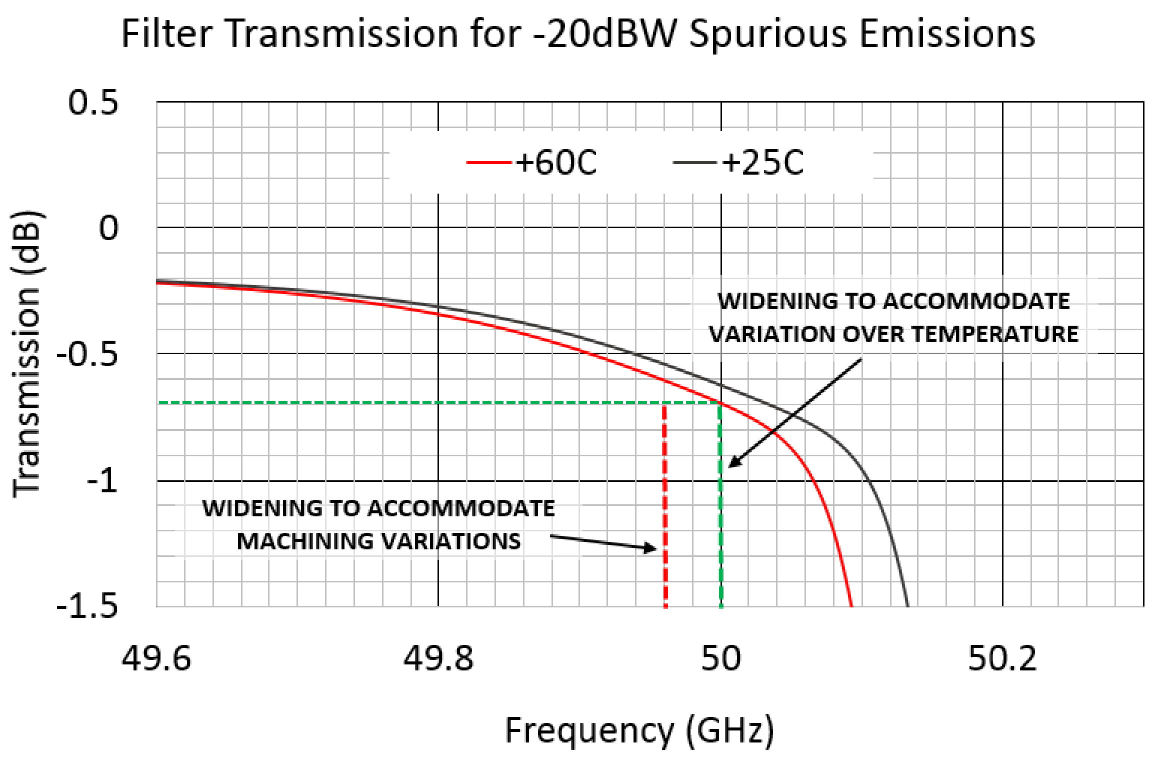
- If the spurious emissions limit were increased to permit -20dBW emission from the amplifier within the 50.2 to 50.4 GHz band, the filter transition width would be considerably reduced
- The accompanying figure shows the detail of the passband edge for a filter that would hold emissions below a -20dBW limit (with manufacturing margin) within the notch, accounting for variation of all parameters over temperature.
- The relaxation of the spurious limit would reduce the required transition band from 400MHz on each side of the notch to 240MHz on each side, increasing usable bandwidth by 320MHz relative to the conditions required for -70dBW spurious emission



SUMMARY

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- The very stringent requirements proposed by certain administrations regarding limiting spurious emissions in the 50.2 – 50.4 GHz band (e.g. -60 to -70 dBW) would require the use of a high-order filter at the output of the amplifier

- Even an ideal filter would have transition bands that would eliminate 400MHz of usable bandwidth outside the 50.2 -50.4 GHz band

- Real effects in the filter – loss, thermal expansion effects and machining tolerances – further decrease the usable bandwidth in the 47-51 GHz band, potentially causing the elimination of a total of ~1GHz of usable bandwidth in order to reduce emissions in the 50.2 – 50.4 GHz band to the above proposed regulatory limits

- Reducing the stringency of the spurious limitations would, in turn reduce the rejection requirements and allow more of the surrounding bandwidth to be used by the satellite transmission system, specifically a relaxation to -20dBW emission in the 50.2 – 50.4 GHz would increase usable bandwidth by ~320 MHz

THANK YOU

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